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SEPTEMBER 1 1919 SERIAL NO. 186

# THE MENTOR

## THE STORY OF THE LENS

By

FLOYD L. DARROW

DEPARTMENT OF SCIENCE

VOLUME 7
NUMBER 14

TWENTY CENTS A COPY

# LENSES

WHAT noble service do we get from these convex and concave pieces of glass—more precious in value than the rarest and most radiant gems! They correct our erring vision and restore our dimming sight. They open up fresh worlds of observation and lead us into strange and unknown paths of knowledge. Through their crystal disks we look up into the eternal fields of light and count the shining flowers of the sky; we gaze down into the tiniest particles of matter and find new forms of life.

By virtue of mere glass Vision is exalted and its boundaries immeasurably extended. By means of mere glass we may hope to penetrate the veiled mysteries of Nature and search out the secret sources of Life.

W. D. M.


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THE MENTOR · DEPARTMENT OF SCIENCE
SERIAL NUMBER 186

# The Story of the Lens

By FLOYD L. DARROW
*Head of Science Department, Polytechnic Preparatory School, Brooklyn, N. Y.*

*MENTOR GRAVURES*

TABLE EQUIPPED FOR OPTICAL GLASS GRINDING

PACKING 100-INCH TELESCOPIC MIRROR FOR MT. WILSON OBSERVATORY, CALIFORNIA

TELEPHOTOGRAPH

Courtesy the Warner and Swasey Company Cleveland

THE ANATOMY OF AN OBSERVATORY

From a model showing skeleton structure of observatory at Victoria, B. C. The actual building contains a 72-inch reflecting telescope under a 66-foot dome

*MENTOR GRAVURES*

ULTRA-MICROSCOPE

GREAT NEBULA IN ANDROMEDA

THE PERISCOPE

WHEN and where the first crude experiments with optical glass were made, no record discloses. Certain it is that the art of glass making goes back to the very dawn of civilization. But the discovery of the optical properties of glass and their utilization in instruments for the aid of human sight is of much later origin. Burning glasses were used by the Greeks and Romans. By their aid the sacred fires in Roman temples were rekindled on those rare occasions when, by chance, they had been allowed to die out. Stories are told of the wonderful effects produced by the ancient scientist and philosopher, Archimedes (ark-e-mee′-dees), with his burning glasses, it being reported that at the siege of Syracuse he set fire to the Roman ships by this means. The ancients, however, had no knowledge of the

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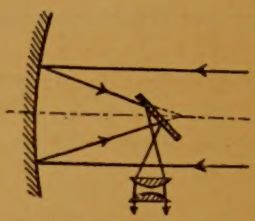
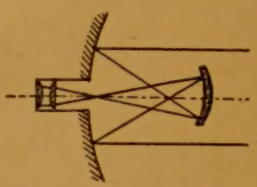
application of glass to spectacles. The eminent American optician, Mr. John A. Brashear, places the date of this discovery as being "somewhere between 1280 and 1311." Preserved in an Italian library is a manuscript written in 1299 in which occurs this sentence: "I find myself so pressed by age that I can neither read nor write without those glasses they call 'spectacles,' lately invented."

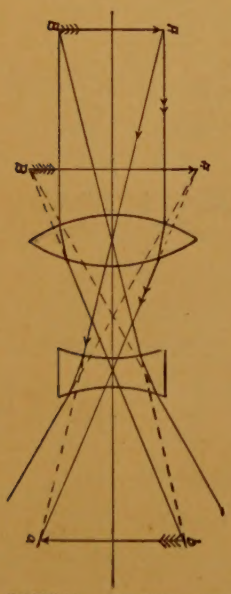


OPTICAL SYSTEM OF NEWTON'S REFLECTING TELESCOPE



OPTICAL SYSTEM OF GREGORY'S REFLECTING TELESCOPE

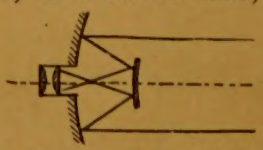
To whom belongs the credit for first having used lenses in some form of optical instrument has never been settled. As early as 1590 a Dutch optician, Zacharias Jensen, placed convex and concave lenses at the ends of a tube about eighteen inches long and used the combination for the purpose of magnifying small objects. A fellow countryman, Johannes Lippershey, a few years later experimented with a similar arrangement of lenses and made the discovery that a distant church steeple was brought much nearer by their aid. But to the genius of Galileo Galilei, Italian musician, scholar, teacher, physicist, inventor and astronomer, the world will forever be indebted for the invention of the astronomical telescope, an instrument that has extended the bounds of human observation by millions of miles.



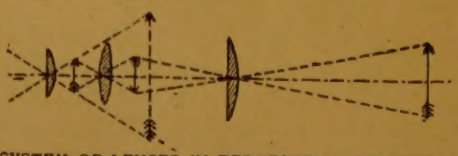
OPTICAL SYSTEM OF GALILEO'S TELESCOPE

## *Galileo's Telescope*

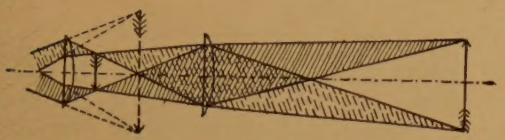
Galileo's telescope, or "Optical Tube," as he called it, consisted of a lead tube in one end of which was a double convex object glass, and, in the other, a double concave eyeglass. With this first instrument he brought objects three times nearer and made them appear nine times larger. He quickly made other glasses, each of higher power than the preceding, and, in a short time, had a telescope that brought objects thirty times nearer than when viewed with the naked eye. With this instrument Galileo made his epoch-making discoveries in astronomy. To his amazement he found that he could count ten times as many stars as his unaided eye was able to detect. Contrary to the common belief, then, the stars were not all equidistant from the earth. Those that were brought into view with his telescope, he concluded, must be at greater distances than those seen without its aid. He next turned his magic tube on the



OPTICAL SYSTEM OF CASSEGRAIN'S REFLECTING TELESCOPE

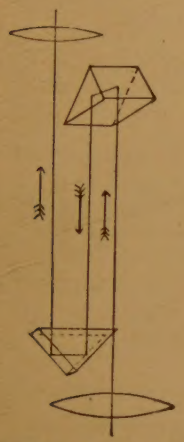


SYSTEM OF LENSES IN TERRESTRIAL TELESCOPE



SYSTEM OF LENSES IN ASTRONOMICAL TELESCOPE

beautiful Milky Way. As a result, this belt of silvery light was resolved into a myriad of stars too faint to be distinguished without optical aid, and at such measureless distances that they literally seemed to rub elbows with each other. And yet this galaxy of stars represents innumerable blazing suns like our own, separated from each other by millions and millions of miles. A still greater discovery was that of the four moons of Jupiter. Here was a miniature solar system, with its central sun and family of revolving planets. In quick succession Galileo discovered that the planet Venus passes through phases as does our moon, he observed the rings of Saturn, studied the surface of the moon, and, by observation of sun spots, proved the rotation of the sun on its axis.

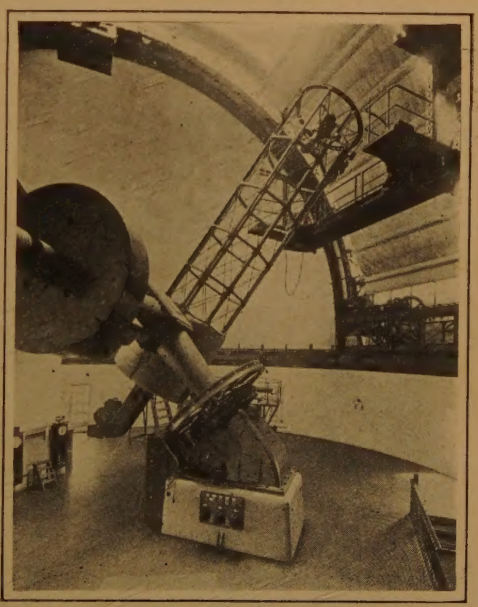


SYSTEM OF LENSES AND PRISMS IN BINOCULARS

## *The Principle of Lenses*

The principle of Galileo's telescope is preserved in the common opera glass. It is of the refracting type, as are all lens telescopes, and to understand the production of images with it we must first become acquainted with the meaning of refraction. Everyone has observed the apparent bending at the water line of an oar looked at obliquely or the misplacement of a line of type when viewed through a thick piece of plate glass. These effects and many other similar ones are due to the bending of the light rays as they pass from a medium of one density to a medium of greater or less density. In passing from greater density to less density the ray is bent away from the perpendicular at the point of incidence, but in passing from a less dense medium to a more dense one it is bent toward the perpendicular. Therefore a ray of light from any part of the oar beneath the water in passing into the air bends away from the perpendicular at the water line. The point from which the light proceeds seems to be in the direction of the refracted ray and consequently above its true position. Now, it is in this power of glass similarly to bend light rays that its optical properties lie. A figure on page 6 shows the bending of a ray of light in passing through a triangular glass prism. A double convex lens with which images are produced is in reality two triangular prisms placed base to base.

Lenses are able to produce two kinds of images—real and virtual. A real image is one that may be focused upon a screen and is produced by the actual meeting of the refracted rays of light at the position in which the image appears to be. Real images are always inverted with respect to the object. A magic lantern picture is an illustration of a real image. A virtual image is not formed by the actual focusing of rays of light but by diverging rays which would meet, only if produced in the opposite direction. A virtual image cannot be caught on a screen

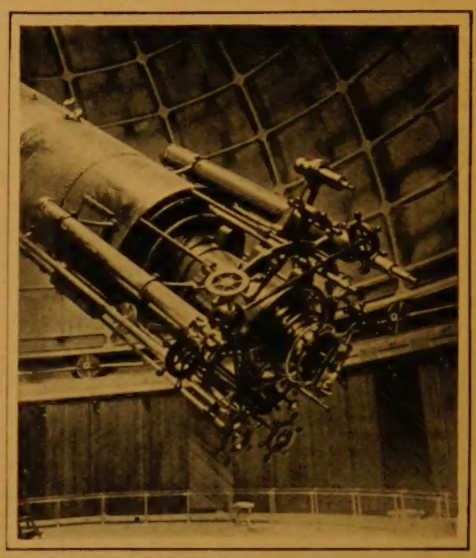


Courtesy the Warner and Swasey Company

SEVENTY-TWO-INCH REFLECTING TELESCOPE
Dominion Astrophysical Observatory, Victoria, B. C.

and it is always upright. An ordinary mirror gives an example of a virtual image. Both types of images are repeatedly illustrated in optical instruments, as will be seen.

There are two main types of lenses, the converging and the diverging. The convex lens belongs to the former class and the concave lens to the latter. As shown in the figure on page 2, the double convex object glass of Galileo's telescope converges the rays of light from the object AB tending to produce a real image at ab. Before the rays reach this position, however, they are diverged by the concave eyeglass and are therefore made to produce a magnified virtual image at A′B′. The eyepiece magnifies by apparently increasing the visual angle, and thus, by causing a distant object to appear larger, it seems to be nearer.



Courtesy the Warner and Swasey Company

EYE-END OF LICK TELESCOPE

Lick Observatory, founded by James Lick, is situated on the summit of Mt. Hamilton, near San José, California

## *Refracting Telescopes*

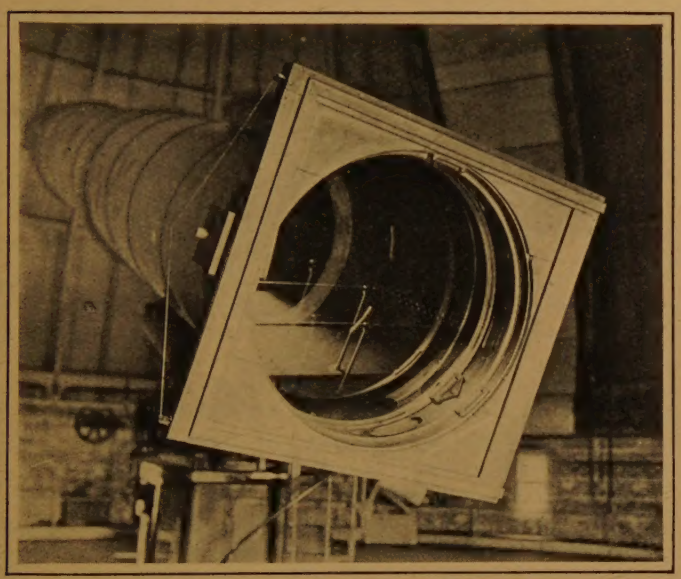
From Galileo until very recent years the refracting telescope has maintained the ascendancy, and it has contributed most to the advancement of astronomical science. But, very early in the making of telescopes, a serious obstacle presented itself. Sir Isaac Newton discovered that prisms and lenses bend rays of different colors unequally. The violet rays are refracted most and the red least. Therefore the violet rays are brought to focus nearer the object glass than the red rays and the whole image is surrounded with a fringe of color. But by grinding lenses almost flat and of very great focal length this difficulty was largely overcome. Another and even more serious difficulty, however, immediately appeared, for these flat lenses necessitated very long and unwieldly telescopes awkward to manipulate and requiring a prodigious amount of time and patience in their use. Telescopes were built over two hundred feet in length and with no tube connecting object glass and eyepiece. In one such telescope built by Huygens the object glass was mounted in a small swivel on the top of a tall pole and secured in position by a rope held taut by the observer, who also held the eyepiece in his other hand. Needless to say very little useful observation could be made with such a telescope.

TRANSPORTING THE 100-INCH REFLECTOR FOR THE SOLAR OBSERVATORY OF THE CARNEGIE INSTITUTION

To the top of Mt. Wilson (6,665 feet), near Pasadena, California

In 1733 Chester More Hall and later, in 1755, John Dollond, two English

opticians, working independently of each other, made the first achromatic lenses. These lenses eliminated to a large extent the disagreeable color fringes about the images produced by refractors. This was accomplished by using an object glass made of two lenses instead of one. A double convex lens of crown glass was cemented to a plano-concave lens of flint glass. Now, flint glass is considerably more dense than crown glass and has a greater power to disperse light into its component colors. And since the double convex crown glass converges the light while the plano-concave flint glass diverges it one lens neutralizes the color effect of the other and a colorless image results. The refractive power of the convex crown glass is greater than that of the concave flint glass, however, and therefore the light is still brought to focus and an image produced. Without this most important discovery no great refracting telescope would have been possible. The progress in the manufacture of optical glass toward the close of the last century has also contributed to this end. With these discoveries the only limitation to the building of refractors seems to be the casting of the large discs of glass.



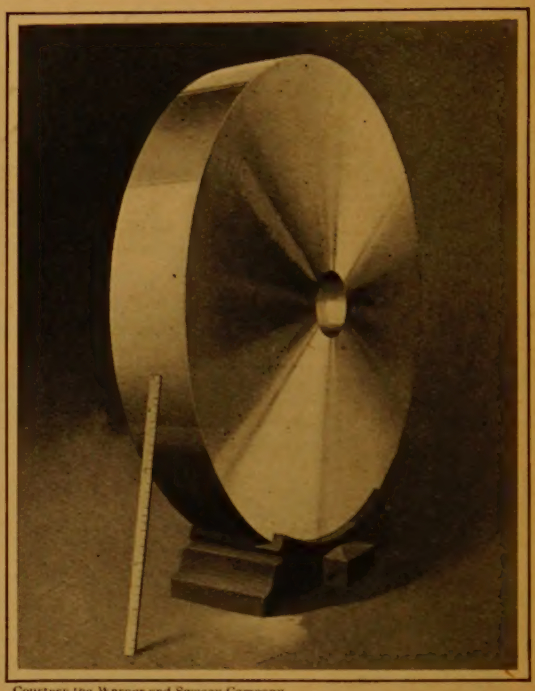
FORTY-INCH REFRACTING LENS MOUNTED
Yerkes Observatory, Williams Bay, Wisconsin

### *Reflecting Telescopes*

But long before the invention of the achromatic lens, Newton, despairing of success with the refractor, had built the first real reflector in 1670. The principles of this form of telescope had been previously explained and embodied in a crude instrument by Gregory, whose name is attached to one of the reflecting systems. The principal types of reflecting telescopes are illustrated in figures on page 2. In each one a large concave mirror, gathers the light and reflects it to a second mirror, plane, concave or convex. This second mirror reflects the light into an eyepiece which produces a magnified image of the object. The eyepiece carries two plano-convex lenses and is really a compound microscope. The reflecting mirror was entirely free from chromatic aberration (disturbances in the rays of light), so troublesome in the refracting telescope and many reflectors were constructed. The "leviathan" built by Lord Rosse in 1845 was six feet in diameter and the mirror was of speculum metal, an alloy of copper and tin. These mirrors are now made of glass with a thin film of silver deposited upon the front surface. As this film becomes tarnished it is removed with acid and the mirror resilvered. A famous grinder of mirrors and builder of telescopes was Sir William Herschel, who, in the eighteenth century, made many important discoveries, notably that of the planet Uranus.

On comparison of the two types of telescopes, we find that the refracting telescope suffers less loss of light, gives better definition and is less clumsy to manipulate than the reflector. Some of the great refractors are the 18-inch telescope of 1861 now at the Northwestern University, the 26-inch glass ground for the United States Naval Observatory in 1871, the 30-inch telescope erected at Pulkowa, Russia, in 1881, the big 36-inch Lick telescope completed in 1888, and finally the giant

40-inch Yerkes refractor built in 1897 and still unsurpassed.



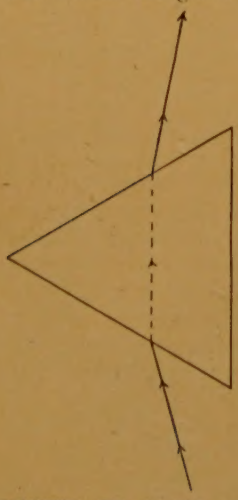
Courtesy the Warner and Swasey Company

GREAT MIRROR USED IN CANADIAN REFLECTOR
Victoria, B. C.
Produced by the John A. Brashear Company, Pittsburgh

### *Making a Great Lens*

The making of a great lens presents a task of unparalleled difficulty. It requires the highest skill and the utmost patience. From the selection of the raw materials for the melt to the removal of the last blemish from the surface of the lens and the final test of its optical qualities, it is a work of extreme scientific precision and accuracy.

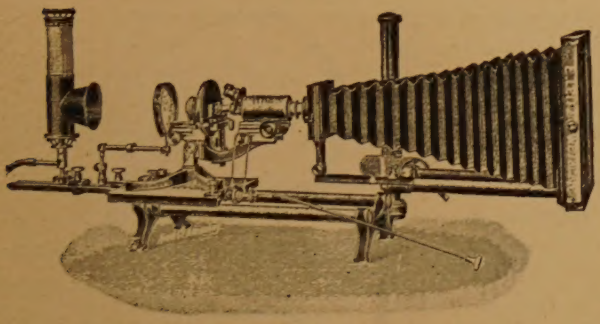
The big crucible in which the glass is melted has been made of the purest clays and by specially trained craftsmen. Previously to receiving the "batch" materials it is heated very gradually for a week to a high temperature. The melting and stirring, under perfect temperature and physical control, proceed for days. Then, when the master workman knows that the glass is ready, the crucible is lifted from the furnace and its molten contents of dazzling brilliancy are poured into an iron mould lined with sand. The mould is covered with an iron plate and lifted into an annealing furnace. There it remains for nearly a month, very gradually cooling from its high initial temperature down to ordinary temperature. And right here is one of the critical stages of the process, for if the annealing is not properly done, the glass will be subject to strains and inequalities that render it useless for optical purposes. When cold the glass passes through its first grinding and polishing stage, preliminary to the very careful examination for imperfections.



BENDING OF A RAY OF LIGHT IN PASSING THROUGH A TRIANGULAR GLASS PRISM

Even this preliminary grinding requires several weeks. For the inspection of the glass the camera, the microscope and an instrument called the polariscope are used. With the camera a perfect piece of glass yields a pure white picture, whereas strains in the glass will produce dark colored spots at those points. When viewed with the polariscope the glass must be perfectly bright and free from irregularities and figures. Some bubbles may pass, but veins, indicating incomplete fusion of the ingredients, strains and spots of unequal density are not permissible. If these defects are found the glass must be returned to the furnace and the process repeated. And this frequently must be done many times. The big 36-inch refractor for the Lick Observatory was poured twenty times at the Paris glass works, with one month consumed for annealing after each pouring.

When a piece of glass has passed this very rigid examination it is ready for the skilled lens grinder, who polishes its sides with the utmost care and in accordance with the curvatures calculated by the mathematician. The man who first applied pure mathematics to the calculation of the correct curvatures of lenses, both for astro-



UNIVERSAL PHOTOMICROGRAPHIC APPARATUS
(Horizontal position)

nomical and microscopic lenses, thereby reducing this art to an exact science, was Professor Abbe of Jena.

For grinding, the big lens is cemented with pitch to an iron plate mounted on a spindle. Emery or some other abrasive is sprinkled on the glass and another iron plate placed above, which is shoved hither and thither over the surface. Finer and finer grinding materials are used, and for the final polishing cloth covered tools and rouge. Very frequent tests of the glass are made. Pieces are chipped off and examined with the spectrometer for their indices of refraction. It is upon these measurements that the mathematical calculation of the curvature is based.

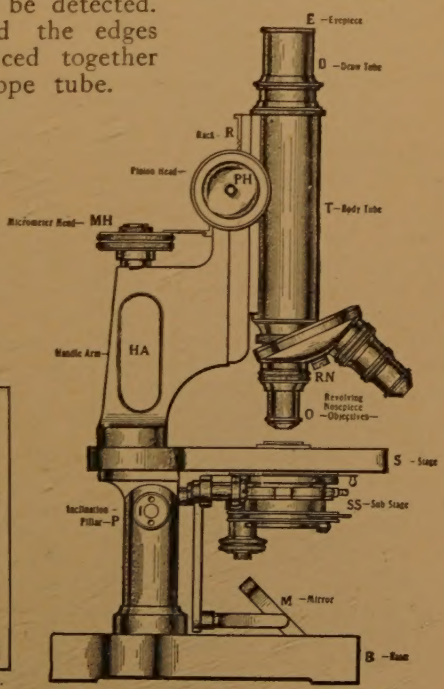
As already shown, a telescope objective consists of two lenses: one convex and made of crown glass, the other concave and made of flint glass. Therefore two lenses must be ground simultaneously and fitted together with the utmost precision. In the final grinding and polishing, tools having an exactly opposite curvature to that required in the lens itself are employed. In testing the accuracy of this curvature, the lens is placed in a "test glass" also of exactly opposite curvature. Between the two surfaces of glass will be a very thin film of air which will give rise to a color effect just as is observed in soap films viewed in sunlight. When the thickness of this air film is everywhere the same, the color appearing will be uniform over the whole surface. In this manner deviations in curvature of only one two-hundred-fifty-thousandths of an inch may be detected. Each lens is then centered in a lathe and the edges ground, after which the two lenses are placed together and mounted for final testing in the telescope tube.

## *Uses of the Lens*

Try to imagine for a moment what this world would be without spectacles, the camera, the microscope, binoculars, field glasses and the stereopticon, and you will only just begin to appreciate something of the immense significance of the lens in the affairs of men.

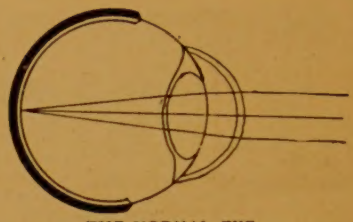
The purpose of a lens always is so to bend the rays of light passing through it as to form an image of some object, or to assist in the formation of an image. The ordinary hand magnifier affords one of the simplest illustrations. We hold it a certain distance from an object, and a magnified image appears. This is a virtual image. It could not

Courtesy P. O. Gravelle, South Orange, N. J.
LARVA OF MOSQUITO
Magnification 14 diameters

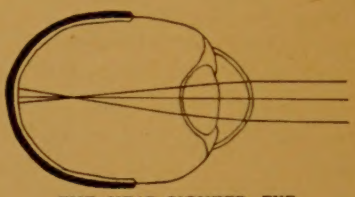



Courtesy Bausch and Lomb Optical Company, Rochester
A STANDARD MICROSCOPE

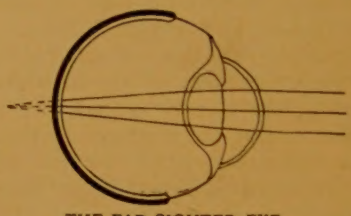
be caught on a screen and one must look through the lens in order to see it. Every lens has a principal axis and a principal focus. The principal axis is a line passing through the optical center of the lens and at right angles to both surfaces. The point where all the rays parallel to this principal axis meet after passing through the lens is the principal focus. On account of what is called "spherical aberration" the rays near the edges of the lens are refracted most and come to focus nearer the lens than the other rays. This condition must be corrected in all lenses used in optical instruments. The focal length of a lens is the distance between its optical center and the principal focus. With converging lenses if an object is placed outside the principal focus, a real, inverted image will result. If placed inside the focus, a virtual image, erect and magnified, is formed. The size of the real image will depend upon the distance of the object from the lens, and may be smaller, larger, or of the same size as the object.



THE NORMAL EYE
The image of a distant object is brought to focus on the retina



THE NEAR-SIGHTED EYE
The image of a distant object is brought to focus in front of the retina



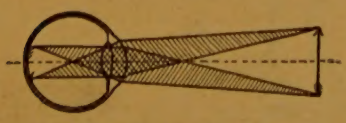
THE FAR-SIGHTED EYE
The image of an object is brought to focus behind the retina

## *The Human Lens*

The most wonderful lens in the world is in the human eye. No other lens has the power automatically to change its focal length to meet the varying conditions of near and far objects. Back of the cornea, the transparent window of the eye, lies the crystalline lens in front of which is a watery liquid called the aqueous humor, and, behind it, a gelatinous medium termed the vitreous humor. At the back of the eyeball the optic nerve spreads out in the retina, the part of the eye that is sensitive to light.

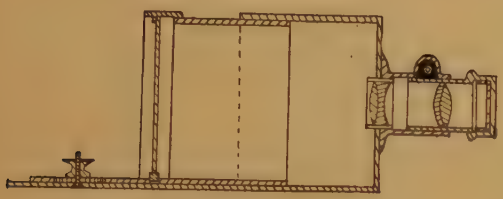
The crystalline lens and the aqueous and vitreous humors have the power to refract light, just as any other lens has. The rays of light entering the pupil of the eye are brought to focus on the retina, where a real inverted image of the object is formed. That we see objects erect, is due to our own mental interpretation of the images on the retina. A normal eye when relaxed will focus clearly on the retina objects which are at a considerable distance. This is because the principal focus of the optical system under those conditions comes at the retina. If the eye turns from a distant object to one near at hand, in order still to bring the image on the retina, either the focal length of the lens must change or the distance between the lens and the retina must increase. In the camera we increase the distance between the plate and the lens, but, in the eye, a ring of muscle around the crystalline lens causes the lens to become more convex, thereby shortening its focal length just the right amount to produce the image on the retina.

To a near-sighted person the image of a distant object is brought to focus in front of the retina. This is due either to too great convexity of the crystalline lens or to excessive elongation of the eyeball. In order to throw the image back on the retina and produce a distinct image, such a person must bring objects close to the eye. If this defect is to be corrected, lenses that will diverge the rays of light and prevent their focusing so soon must be used. Therefore spectacles with concave lenses—thick at the edge and thin in the middle—are employed.



PRODUCTION OF AN IMAGE BY CRYSTALLINE LENS OF EYE

In the far-sighted eye the image of a nearby



THE CAMERA AND ITS LENS

object is focused behind the retina because the crystalline lens is too flat or the eyeball is too short. To bring the image up onto the retina a far-sighted person holds objects off at a distance. In this case a lens that will converge the rays of light and bring them to focus earlier must be used. Spectacles with convex lenses will correct this defect.

Astigmatism is due to the fact that the refractive power of the eye is different in different planes. This results in more distinct vision in some directions than in others. A star, for example, is seen as a line of light. If a series of intersecting lines at all angles are drawn the astigmatic eye will see distinctly only those in a certain plane, the others appearing broad and blurred. This defect is corrected by wearing cylindrical glasses so ground as to reinforce the power of the eye in the plane of least curvature, or to neutralize the excessive curvation of the opposite plane.

## *The Camera*

Aside from the use of lenses in spectacles, no other adaptation has become so universal as that of the camera. But just as the telescope objective passed through a long period of evolution, so has the camera lens. Under a succession of masters of optics and scientific glass makers lenses to meet every need of the amateur and professional photographer have been perfected. Curvatures have been calculated with mathematical precision, and glass has been balanced against glass and element against element until every distortion and aberration has been compensated for.

One of the chief differences in camera lenses is length of focus. The longer the focal length the larger the image and the better the perspective. With a six-inch lens the image will be twice as long as it will with a three-inch lens. It is a matter of common experience, too, that most objects have a more pleasing perspective when seen from a distance. Likewise pictures taken with a long focus lens are in true perspective, whereas if a short focus lens is used there is serious distortion. With a long focus lens, however, the field of view is more limited.

Just as the telescope objective had to be corrected for the unequal refraction of light of different colors, so, too, did the camera lens. The result was the single achromatic meniscus lens followed by a combination of two such lenses with the stop between the two. This latter lens is called a "rapid rectilinear" lens because it gives straight line images and corrects the curvatures produced in the lines of an image taken with the single achromatic. When, toward the close of the last century, new and better kinds of optical glass were made the anastigmatic lens was produced. Unlike its predecessors, this lens will not only bring all the colors to the same focus, but it will also give flat field images in place of the saucer-shaped ones of the "old" achromats.

EXAGGERATION PRODUCED WITH SHORT-FOCUS LENS

Photographs courtesy Eastman Kodak Company

CORRECT PERSPECTIVE OBTAINED WITH LONG-FOCUS LENS

Courtesy Scientific American

PART OF SOLAR SPECTRUM

The manufacture of camera lenses has become a highly specialized art, as rigidly exact and painstaking as the making of a large refractor. So large must be the output of these lenses that much of the hand grinding and polishing has long since been superseded by the motor-driven machine. And yet the skilled artisan is as indispensable as ever. The grinding is carried to an accuracy of one fifty-thousandth of an inch. Then, after a most critical inspection, each lens is centered in a lathe and mounted.

## *The Microscope*

If it may be said that the telescope has brought to our knowledge new worlds without end, so is it equally true that the microscope, penetrating the universe in the opposite direction, has revealed systems of life and matter as truly marvelous as the infinite depths of space.

Until 1870 the compound microscope was a very imperfect instrument. Up to that time it had been built on the same general plan as the telescope. Its defects were fully appreciated, but no one knew how to remedy them. Then Professor Abbe of Jena, the master genius of modern optics, attacked the problem and successfully solved it. He corrected every aberration and designed an objective which is today the basis of all compound microscopes. In this objective are six lenses, the smallest of which is only one-sixteenth of an inch in diameter. The machinery for grinding it is a marvel in itself, and the grinding is done by trained technicians who have worked at the art from boyhood. They can tell by touch the progress of the work, and the finished product must be as perfect as the largest refractor.

As the name signifies, a compound microscope gives double magnification. The objective itself frequently gives a primary magnification of 95 diameters, which is multiplied by the eyepiece to 1,200 diameters. This is about the limit for practical work, although magnifications of 3,000 diameters are possible. Coupled with the camera and the arclight, the microscope gives the microphotograph. Magnifications up to 3,000 diameters are said to have been actually photographed. The value of the microscope to science can hardly be estimated. Biology, bacteriology, the causes of disease, a knowledge of the structure of metals and crystals, have all been made possible through its marvelous powers of penetration. The wave length of light, itself, has imposed a limit to these powers, and further magnification is impossible. But just as this crisis arrived the

Courtesy Eastman Kodak Company

SETTING DISKS IN GRINDING SHELL

Courtesy Eastman Kodak Company

ROUGH DISKS OF OPTICAL GLASS

ultra-microscope, elsewhere described, came to the rescue and its possibilities are not yet exhausted.

### *Stereoscope and Field Glasses*

A very skilful instrument for producing the illusion of relief is the stereoscope. Provided with two views having the same slight divergence as those received by the two eyes, the stereoscope fuses them into a perfect semblance of depth and solidity. The camera which takes these views is provided with two lenses so placed as to give images exactly similar to those observed with the two eyes. In the war, stereoscopic telescopes of great penetrating power were used. It is said, too, that stereoscopic views were taken from an airplane at points separated by 50 to 100 feet, which viewed through an instrument actually penetrated the enemy camouflage.

Field glasses are as old as Galileo's telescope. The common form of spyglass, or terrestrial telescope, differs from the astronomical telescope in having a second converging lens to erect the image formed by the objective. The erect image is then magnified by the eyepiece. The opera glass is identical in its combination of lenses with Galileo's telescope. Opera glasses are subject to a small field and low magnification, but give good illumination and can be used in a dull atmosphere.

Binoculars having a wide field of view, combined with the compactness of the opera glass, have come into very general use in recent years. The light is made to pass back and forth between two total reflecting prisms, thereby increasing the actual focal length of the object glass three times and correspondingly increasing the magnifying power. The reflections in the two prisms give an erect image and the greater separation of the object glasses gives better stereoscopic effect.

Revealing alike the infinitely small and the infinitely great, the lens has broadened men's minds to embrace a universe of vast extent. And we have not yet reached the end, for the dreamer is still with us, and what new realms he may bring to view with improved methods in optical science, no one dares predict.

Courtesy Eastman Kodak Company

DISKS MOUNTED FOR FINE GRINDING

## *SUPPLEMENTARY READING*

THE BOY'S OWN BOOK OF GREAT INVENTIONS, Chapter XIX, Galileo and the Telescope - - - - - - - - - - - *By Floyd L. Darrow*

STARS AND TELESCOPES - - - - - - - - - - *By David P. Todd*

SIDELIGHTS ON ASTRONOMY, Chapter on Making and Using a Large Telescope *By Simon Newcomb*

REPORTS OF SMITHSONIAN INSTITUTION, Vol. 506, 1904, Construction of Large Telescope Lenses.

ABOUT LENSES - - - - - - - - - - *Eastman Kodak Company*

*** Information concerning the above books may be had on application to the Editor of The Mentor.

# THE OPEN LETTER

It should be a matter of no little pride to Americans that all the great refracting lenses of the world have been ground in the United States. The firm that has done most of this work is that of Alvan Clark and Sons, of Cambridgeport, Massachusetts. Alvan Clark, the father, (1808–'87), was the son of a New England farmer, and taught himself engraving and portrait painting. It was while he was a portrait painter in Boston that he became interested in the manufacture of telescopes. In 1844 he constructed a small reflector, the success of which led him to the grinding of lenses. It was not long before the reputation of the Clarks, father and son, as lens manufacturers became known the world over. In this great work the Clarks have won imperishable fame. Alvan Graham Clark, the son (1832–'97), joined in his father's work at an early age, and it is under his direction that some of the finest lenses have been made. Five times between 1860 and 1892 the Clark firm was called upon to construct "a telescope lens more powerful than any in existence," and each demand brought forth a greater glass, ending with the giant Yerkes refractor. This famous lens is forty inches in diameter, weighs a ton and a half, and cost $125,000. Its purpose, as that of every other large telescope lens, is not to magnify but to gather more light, and to increase the number of rays that can be brought upon the retina. Since its area is forty thousand times greater than that of the pupil of the eye, it is able to make a star appear forty thousand times brighter than when seen with the unaided eye. Each of the large refractors have, in turn, brought to view millions of new stars and widened the universe by billions of miles.

ALVAN G. CLARK SEATED BESIDE THE GREAT 40-INCH YERKES LENS

Other large refracting telescopes are the 36-inch at Lick Observatory, Mt. Hamilton, California, the 26-inch at the U. S. Observatory at Washington, D. C., the 24-inch at Harvard University, Cambridge, Massachusetts, and the 30-inch at the Alleghany Observatory, Riverview Park, Pennsylvania. In Europe, the famous lenses are the 30-inch at the Imperial Observatory, near Petrograd, Russia, the 32-inch in the Meudon Observatory, near Paris, the 32-inch at the Nikolaieff Observatory, Russia, the 31-inch at Potsdam, Prussia, and the 28-inch at the Royal Observatory, Greenwich, England.

★ ★ ★

These are the great lenses of the world. The famous reflectors are much larger. Two of the most remarkable reflecting telescopes ever put in place are in the observatory on the summit of Mt. Wilson, near Pasadena, California. One of these mirrors is made of silver on glass, has a diameter of 60 inches and weighs nearly a ton. The other mirror has a diameter of 100 inches; the tube that supports the mirror is 43 feet long, and, together with its mountings, weighs about 20 tons. Besides its giant lens, the Lick Observatory is equipped with a 36-inch reflector. At Harvard University there are two reflectors—60-inch and 28-inch. Next in size is the 24-inch reflector at Yerkes Observatory. Outside of the United States there are still more powerful reflectors—the 72-inch at the Dominion Astronomical Observatory, Victoria, B. C., the reflector of similar diameter at Biru Castle, Ireland, the 61-inch at the National Astronomic Observatory, Cordoba, Argentina, the 60-inch at Ealing, England, the 48-inch reflectors at Melbourne, Australia, and Paris, France, and the 39-inch at Meudon, France.

W. D. Moffat

EDITOR

ONE

THE manufacture of optical glass is the most difficult task of the glass maker's art. It presents problems requiring, for their solution, the technical training of the research chemist, the mathematical ability of the physicist and the skill of the expert craftsman. From the time of Galileo to the Great War optical glass was made entirely in Europe—principally in Germany. There, under the direction of Professor Abbe, the early master of optics, and Doctors Schott, Carl and Zeiss, this art had been brought to a high state of perfection. Every wearer of spectacles as well as any user of any optical instrument was dependent upon the furnaces beyond the Rhine for the glass from which these instruments were made.

But back in 1853 John J. Bausch went to Rochester and began, in a very small way, the grinding of superior lenses that soon attracted the notice of New York opticians. A most disconcerting feature of his work, however, was the fact that all of his glass had to be imported. Long and persistently he sought to solve the problem of making glass that would meet the high requirements of his art. Then came the war, and what had been only a highly desirable goal, at once, became a necessity and a patriotic duty. After three years of diligent research, interspersed with many temporary failures, Bausch, now nearly ninety years old, assisted by his son, William, succeeded in making optical glass of a very high grade.

When the United States entered the war it became imperative that the Government should have large quantities of glass for range finders, gun sights, periscopes, search-light mirrors, photographic lenses and binoculars. Immediately the Bureau of Standards and the Geophysical Laboratory at Washington took up the problem and Major F. E. Wright, Ph. D., was detailed to take charge of the work. A number of glass manufacturers throughout the country placed their plants at the service of the Government.

There are six fundamental requirements of good optical glass: (1) Correct optical and physical properties; (2) freedom from striæ; (3) freedom from bubbles; (4) high light transmission; (5) freedom from color; (6) freedom from strain. To meet all these requirements there were necessary a stirring device that would eliminate the striæ, or tiny grooves, melting pots more resistant to corrosive fluxes and freer from iron and sulphur than any then being made in the United States, and the purest "batch" materials. Most essential, too, were skilled workmen of whom there were none in this country at that time. As the result of an amount of technical and practical experimentation unprecedented in the history of the glass industry, these conditions were successfully and quickly met.

The two principal kinds of glass used in optical instruments are crown glass, consisting essentially of silica, potash, soda and lime, and flint glass, consisting of silica, potash and lead oxide. Small quantities of other substances, as boric acid, magnesium, zinc, barium and antimony are also used. Silica is ordinary sand and is always contaminated with iron oxide, from which it must be freed. This is accomplished first by passing a huge magnet over it, and then washing the sand with acid and water.

The first step in the manufacture of optical glass is to preheat the clay pot through a period of seven days to a temperature of 2500 degrees F. Into this are weighed at intervals of fifteen minutes for one hour 100 pounds lots of cullet, *i.e.*, optical glass of inferior quality from a previous melt. This is followed with pure batch materials in successive lots of 400 pounds each at intervals of two hours accompanied by hand stirring for periods of fifteen minutes each. The mass is then machine stirred for four hours, when the pot is removed from the furnace, covered with earth and allowed to cool, or anneal, slowly for four days. The pot is now broken away and the chunks of glass sent to the examination room. All portions not having the qualities of good optical glass are sent back to be used as cullet for another melt, while the good glass goes to the press room. In the press room the chunks are slowly preheated until soft, and then pressed into slabs in hydraulic and pneumatic machines. After annealing, these slabs are laid in frames on a grinding table covered with fine sand or emery and ground to a smooth surface. They are then polished by driving to and fro over their surfaces an iron block covered with felt and rouge. Rigid inspection for striæ and bubbles follows. The latter are detected by looking through the slabs toward a dark cloth while a narrow ray of light enters the glass at right angles to the line of sight. Defective places are marked and removed by sand blast. All accepted glass is reheated, pressed and very slowly annealed.

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FROM the days of Galileo and Sir Isaac Newton astronomers have persistently sought to bring to perfection the two great types of telescopes—the refracting and the reflecting—and to demonstrate, if possible, the superiority of one or the other. After the immense six-foot reflecting mirror made by Lord Rosse and now in the British Museum, all the big telescopes for nearly a century were of the refracting type, and not until the last decade has the reflector once more gained the ascendency. The two largest reflecting mirrors ever ground were recently completed, one for the Solar Observatory at Mount Wilson, California, and the other for the Dominion Astronomical Observatory at Victoria, Canada.

The making of a telescope mirror is a long and most exacting process. It begins with the manufacture of the glass and ends only when the mirror has been placed without mishap at the bottom of the great telescope tube. The order for the glass to be used in the mirror for the Mount Wilson observatory was given to a French firm in 1906 and the glass was delivered at Pasadena, California, in 1909. Because the rough block of glass seemed to reveal serious flaws, it was decided to make on the spot glass of a better quality. Accordingly a furnace capable of holding twenty tons of molten glass was built and a year wasted in demonstrating the futility of the proposition. The glass was either hopelessly defective or was broken in removing it from the furnace. Then in 1910, under the direction of Prof. George W. Ritchey of the Mount Wilson observatory staff, the grinding of the previously rejected piece of glass was begun. The block weighed 4½ tons and the grinding required three years. The completed mirror is 101 inches in diameter and 12¾ inches thick at the edge. Its greatest depth of curvature, *i. e.*, departure from the horizontal surface, is only 1¼ inches. The surface is slightly parabolic and yet at its center deviates from a true spherical form by only one-thousandth of an inch. A deviation of more than one two-hundred-thousandth of an inch from the theoretical form calculated by the mathematician is positively not permissible. No wonder three years are required for grinding such a mirror!

Two other convex mirrors of approximately 29 and 25 inches aperture respectively were also ground to use in conjunction with the big 100-inch mirror. The focal length of the large mirror alone is 42 feet and when combined with the other two mirrors gives focal lengths of 150 and 251 feet. The telescope may be used in the Cassegrain, Coude or Newtonian combinations and with spectroscopic or photographic attachments.

The big reflecting mirror for the Dominion Astronomical Observatory is 73 inches in diameter, 12 inches thick at the edge and is pierced by a hole 10⅛ inches in diameter to permit of its use as a Cassegrain telescope. Its silvered surface is a parabola in form and reflects the light to a focus 30 feet distant. The mirror weighs 2¼ tons but is supported so perfectly in its containing cell that not the slightest distortion can occur. As a Newtonian telescope in which the image produced by the mirror itself is viewed directly with an eye-piece the focal length is that of the mirror—30 feet. When used with the second convex reflecting mirror as a Cassegrain telescope the focal length is 108 feet. The mirror was made by the John A. Brashear Co. of Pittsburgh and the telescope was designed and constructed by the Warner and Swasey Co. of Cleveland.

The purpose of a large telescope mirror is not to magnify but to gather light and to produce an intensely bright real image which may be observed with a magnifying eye-piece. The eye-piece is really a very powerful compound microscope and yet the largest telescope is unable to magnify a single star, so distant are they. The larger the mirror the longer its focal length and the more light it will gather. The human eye gathers very little light and stars fainter than the sixth magnitude are invisible. Not more than 5,000 thousand can be counted without the aid of a telescope. Up to the building of the giant reflector at Mount Wilson there existed approximately 219,000,000 telescopic stars; but it is now hoped that the population of the stellar universe may be increased by at least 100,000,000. These telescopes, too, have been especially designed for spectroscopic and photographic work. In these marvelous creations of astronomical engineering once more new standards have been set for human endeavor and attainment.

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PACKING 100-INCH TELESCOPIC MIRROR FOR MOUNT WILSON OBSERVATORY, CALIFORNIA

# THE STORY OF THE LENS

## *Photographing at a Distance*

THREE

THE photographing of objects at great distances—the lonely mountain peak, architectural details, inaccessible bits of scenery, birds and animals in their native haunts—was all impossible until the introduction of the telephoto lens about thirty years ago. With the ordinary short-focus lens used at a distance, great mountain peaks seem only little hummocks of rock and snow. The richly sculptured front of some Old-World cathedral is wholly lacking in the detail and artistry for which it is chiefly interesting. The photographs of vivid and realistic scenes of war which grip the observer with feelings almost akin to actual participation are products of the telephoto lens or the long focus cameras so much used in the Great War.

The telephoto lens is really a photographic telescope. It applies to the camera the same principle that is utilized in an ordinary opera glass. In the opera glass a concave or diverging lens is placed behind the converging objective and the result is a magnified erect image. Likewise the telephoto attachment consists of an adjustable tube having in the front the regular photographic lens and behind it at the other end a concave lens to diverge the rays of light and give a magnified image on the ground glass plate. Through a rack and pinion the separation between the two lenses may be varied and an optical system of variable focal length secured. This variation is from three to eight times that of the regular lens, and, therefore, magnifications of the image in the same ratio are obtained. In this wide range of focal lengths lies one of the chief advantages of the telephoto lens. In addition, the required bellows extensions are, in all cases, considerably shorter than the resulting focal lengths of the optical system would indicate, and, therefore, more compact camera outfits are possible. An important disadvantage of this lens is that a longer exposure is required. The necessary exposure varies as the square of the magnification. If the telephoto system is adjusted for an increase in the focal length of three times, an increase of exposure of nine times over that for the regular lens alone would be required.

As may be inferred from what has already been said, the size of the image produced by a lens depends upon its focal length. For distant objects the size of the image increases directly with the increase in focal length. With the focal length three times as great, the image will be three times as large. But the intensity of light on the plate or film will be less; hence the longer exposure required. Because of this impossibility of making instantaneous exposures with the telephoto lens it was found necessary for war work to develop high speed, long-focus lenses with cameras having long bellows extensions. Taking photographs of troops in action, or of belching cannon, or making exposures from an aeroplane were out of the question with the telephoto lens. Great progress has been made in the development of long-range cameras during the war. The French used one type having a bellows extension of four feet. Such cameras would formerly have been thought too cumbersome and unwieldly to be practicable but the exigencies of war have overcome this difficulty.

One of the chief advantages of long-range lenses is the freedom from distortion so prominent in views of large objects taken at close hand. With the telephoto or camera of long focal length, true perspective is obtained and that richness and vividness of detail so characteristic of modern panoramic photography. Much of the delight which we experience in viewing the splendid travelogue pictures of such noted lecturers as Burton Holmes and Dwight L. Elmendorf must be credited to these types of lenses. So, too, the charm attached to much of modern magazine illustrating and the realistic photography in the picture supplements of the Sunday newspaper. Surely the world owes much to the genius of those masters of optics who have brought to so high a degree of excellence the art of long distance photography.

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PHOTOGRAPHS BY DWIGHT L. ELMENDORF

(A)

PHOTOGRAPH AND TELEPHOTOGRAPH OF [illegible]

FOUR

WHO has not seen the countless myriads of glistening dust motes dancing in some stray sunbeam that has found entrance to a darkened room? But how many realize that this very commonplace experience affords a beautiful demonstration of the principle of the ultramicroscope, an instrument that enables the scientist to come very close, if not quite, to seeing the molecules of matter? The ordinary microscope has reached the limits of magnifying power, and without some new instrument making possible a keener vision and greater depths of penetration that immense universe of life and matter lying just beyond the frontiers of the microscopic world would have forever remained a mystery. But once more the "impossible" has given way before the boldness of the dreamer, and we find ourselves in the very ante-room of the molecular and atomic mysteries.

To be seen, an opaque object must either reflect light or be self-luminous. The ordinary microscope employs direct illumination and the opaque object is made visible by the absence of light, due to the light waves which it cuts off. For light produces waves of definite known lengths in the all pervading ether of space. The limit of microscopic vision is determined by the shortest wave length of light perceptible to the human eye. This length is sixteen millionths of an inch, and, therefore, when an object is less than one-half that amount the wave simply bends about it, just as a water wave encircles a small obstruction, and reuniting moves forward as though no obstacle had been in its path. Hence we see that it is idle to talk of direct vision microscopes of constantly increasing magnifying power.

The ultramicroscope, however, makes these exceedingly minute particles, too small for direct vision, behave as self luminous bodies. It utilizes an ordinary compound microscope to observe objects placed against a dark background and rendered highly luminous by an intensely bright beam of light at right angles to the line of vision. The first substance to be examined in this way was gold dissolved in ruby glass. A converging pencil of light was made to illuminate the glass and behold, the particles of gold stood forth, glistening points of light, like stars in the Milky Way. Although red when viewed by transmitted light, these particles were now green and they danced to and fro in zig zag paths with a very rapid motion.

Four conditions are requisite for success with the ultramicroscope: (1) An intense source of light; (2) no ray of light must be allowed to fall upon the eye either directly or by reflection; (3) a very dark background; (4) the beam of light must be very thin. Directly beneath the microscope objective is placed the dark background stage and to one side an arc light and system of lenses. For solutions a containing cell is placed upon the stage.

One of its greatest uses has been in the study of micro-organisms that cause disease and are so small that they pass freely through the finest porcelain filters. So-called colloidal solutions, which are really very fine suspensions, have afforded the richest field for the investigator. Since colloidal substances make up the greater part of living tissue, their direct examination is of very great scientific interest and importance. The real nature of the bond between the fiber of the fabric and the dyestuff with which it is colored, long a mystery, is revealed by the ultramicroscope. An examination of the blood serum displays countless minute particles hitherto unknown.

But perhaps the greatest service that this new instrument of science has rendered is in the direct confirmation that it gives of the kinetic theory of matter—that is, the theory that the molecules are in a very rapid state of vibration. By its aid we are able actually to see particles that approach very closely to molecular dimensions, and the very rapid motion which they exhibit points to an infinitely more rapid movement on the part of the molecules of the medium in which they are buffeted about. It has often been said that we should never be able to see the molecule but the computed dimensions of the molecules of such organic substances as starch and albumen are well within the limits of the ultramicroscope and actual observation of them is almost an accomplished fact. But the ultramicroscope does not reveal the true appearance of these particles. They seem to be only structureless disks of light like blazing suns rather than planets shining by reflected light, as are the objects of ordinary microscopic vision. The ultramicroscope has broken down one more barrier lying between the truths of the universe and man's incurable yearning to understand them.

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FROM PHOTOGRAPH OF INSTRUMENT IN COLUMBIA UNIVERSITY LABORATORY

ONE of the most remarkable adaptations of magnifying glass to the unraveling of the secrets of the universe is the spectroscope. The world's original and largest spectroscope is to be found in nature itself, for every rainbow that paints the sky is an immense spectrum produced by sunlight shining through falling drops of water. Those bright, flashing pieces of glass called "prisms" are also spectroscopic.

A spectroscope consists essentially of four parts: (1) A very narrow slit through which passes the beam of light, (2) a small telescope called a collimator, at the focus of which the slit is placed, (3) a prism, or a very closely ruled glass plate to disperse the light into its component colors, and (4) an observation telescope to produce a magnified image of the spectrum.

Light is an electromagnetic wave motion in the ether of space. It differs from the vibrations that produce heat, wireless and chemical effects only in its wave length. Wireless waves are very long, frequently a mile or more, while light waves are measured in millionths of an inch. Like musical tones, one is of a very low pitch, the other very high. Color is simply *pitch*, and, within the very short range of the ether waves visible to the human eye, there is a whole scale of color, starting with the red and ending with the violet. The red waves are longest, the violet shortest. When light waves fall obliquely upon one of the faces of a glass prism that portion which enters the glass is retarded in velocity, the shortest waves being retarded most. Therefore when white light passes through a prism the red waves are retarded least and the violet most with the colors of other wave lengths lying between. The result of this unequal retardation, or refraction as it is called, is to separate the light into its component colors.

In 1815 Fraunhofer, an eminent optician, using a spectroscope of higher magnifying power than his predecessors, mapped certain dark lines crossing the sun's spectrum. For many years the meaning of these lines was a mystery. Then, in 1858, Kirchhoff and Bunsen, bringing this instrument to a much higher degree of perfection, discovered the following principles of spectrum analysis: (1) Incandescent solids and liquids and also gases under high pressure give a continuous spectrum, or solid band of color. (2) Gases under low pressure give a series of bright lines whose number and position depend upon the elements present. (3) When white light passes through a gas of lower temperature than its source, this gas will absorb from the white light those colors which it would produce, if viewed by itself in the incandescent state.

At once the meaning of the Fraunhofer lines became apparent. These dark bands were due to elements in the state of incandescent vapor in the sun's atmosphere and they neutralized in the sun's spectrum the colors which they themselves would have emitted. Now every element gives its own characteristic bright line spectrum, the lines being of absolutely definite color and position. Therefore by devising a spectroscope with a comparison prism so that the solar spectrum or that of a star might be viewed side by side with the spectra of terrestrial elements, it at once became possible to determine the chemical composition of any heavenly body whose light would reach our telescopes. And more, this instrument reveals the physical state of stars, nebulæ and comets, for a continuous spectrum means an incandescent solid or a gas under great pressure, while a discontinuous, or bright line, spectrum proves the presence of a light, vaporous firemist. Most of the nebulæ, those worlds in the process of formation, have been shown to be of the latter composition. By replacing the eyepiece of the spectroscope with a photographic plate these spectra may be photographed and studied at leisure. Every great telescope carries a spectroscopic attachment and the light gathered by the great lens or mirror is dispersed by the prism.

The spectroscope discloses the motion of a distant star. When a star is approaching our solar system its spectrum is shifted from the normal position it would occupy if the star were stationary toward the violet. When the star is receding from us the spectrum is shifted toward the red. By the amount of the shifting the velocity may be determined with an accuracy of within two to three miles per second. This shifting of the spectral lines has led to the discovery of twin stars, revolving about a common center of gravity and periodically eclipsing each other. Each star gives its own spectrum and as the lines alternately shift first toward the red and then the violet there can be but one conclusion, that is, companion stars in mutual revolution.

In the hands of the chemist the spectroscope has proved the most delicate means of detecting minute quantities of chemical elements. So small a quantity as one two-hundred-thousandth of a grain of sodium may be detected by this means.

A marvelous instrument is the spectroscope, and its possibilities are not yet exhausted.

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PHOTOGRAPHED BY RICHEY AT YERKES OBSERVATORY, 1901. COURTESY SCIENTIFIC AMERICAN

GREAT NEBULA IN ANDROMEDA

PROBABLY the most skilful adaptation of lenses and prisms to a specific purpose is to be found in the periscope. To throw horizontal rays of light down a long tube and bend them again at right angles, thereby forming an image of some distant object above, was the problem presenting itself to the inventor of the periscope. As invented in 1854 and first used in our Civil War, the periscope consisted of a vertical tube carrying at top and bottom plane mirrors inclined at an angle of 45 degrees to the horizon. In principle it was based on the Polemoscope made by Helvelius in the seventeenth century and consisting of a telescope of the Galilean type but twice bent at right angles. Such a periscope was, however, little more than a toy. It gathered but a small quantity of light and the field of view was very limited, as was also the length of the tube. The great development of the periscope as one of the crowning triumphs of optical progress has come within the last ten years.

The first improvement was to substitute total reflecting prisms for the mirrors but this was only a small gain. When, however, the work of Lake and Holland had demonstrated that the submarine must be seriously reckoned with as a formidable instrument of naval warfare, the necessity for a more efficient periscope became imperative. As shown in a diagram in this issue, the modern periscope preserves the total reflecting prisms at top and bottom and adds to these a system of lenses within the tube and an eyepiece below with which to observe the image. The system of lenses comprises essentially two telescopes. The upper one reduces the size of the image while the lower one magnifies it. A magnification of about one and a half times is required in order to make objects viewed through the periscope appear of normal size. The lens system is such, too, that, although the image is at first inverted, it is afterwards reinverted and therefore appears upright as viewed with the eyepiece. In many of the later types of periscopes a special erecting prism about midway of the tube serves this purpose. The rays of light from a surface object entering the window glass are reflected by the upper prism into the periscope tube, where they are successively refracted by the upper eyepiece, upper objective and lower objective, to the lower prism, which reflects the rays into the lower eyepiece and thence to the observer's eye.

Periscopes are from sixteen to twenty-four feet in length. The direct vision type described above gives a range of about 60 degrees in whatever direction it may point and can be rotated through the whole circle of 360 degrees.

It is of course highly desirable to be able to command the whole horizon in one view and for this purpose a panoramic periscope having a circular object glass has been perfected. This periscope employs a prism at the bottom of the tube and gives a circular field of view including the whole horizon but with a dark spot in the center. To fill this space a direct vision periscope is provided so that in the center is obtained an image of the scene directly ahead while about it is a fringe showing every point of the compass. The circular image always suffers distortion and, therefore, an object is simply picked up in this field but studied in detail with the direct vision periscope. Binocular eyepieces giving stereoscopic depth to periscope images have not seemed practicable and continual observation tires the eye. But in clear weather it is possible to throw these images on a ground glass screen. This is not permissible, however, when exact details are essential.

With the periscope projecting twenty feet above the water a battleship may be picked up at a distance of about six miles in clear weather. With the periscope three feet above the water the range is restricted to about two miles and with only one foot projecting to barely a mile. At night the periscope is of no value unless the moon is shining brightly and even then its use is very limited. Although the periscope may be shot away, water cannot enter the submarine, and, by means of compass and conning tower, escape is assured.

WRITTEN FOR THE MENTOR BY FLOYD L. DARROW
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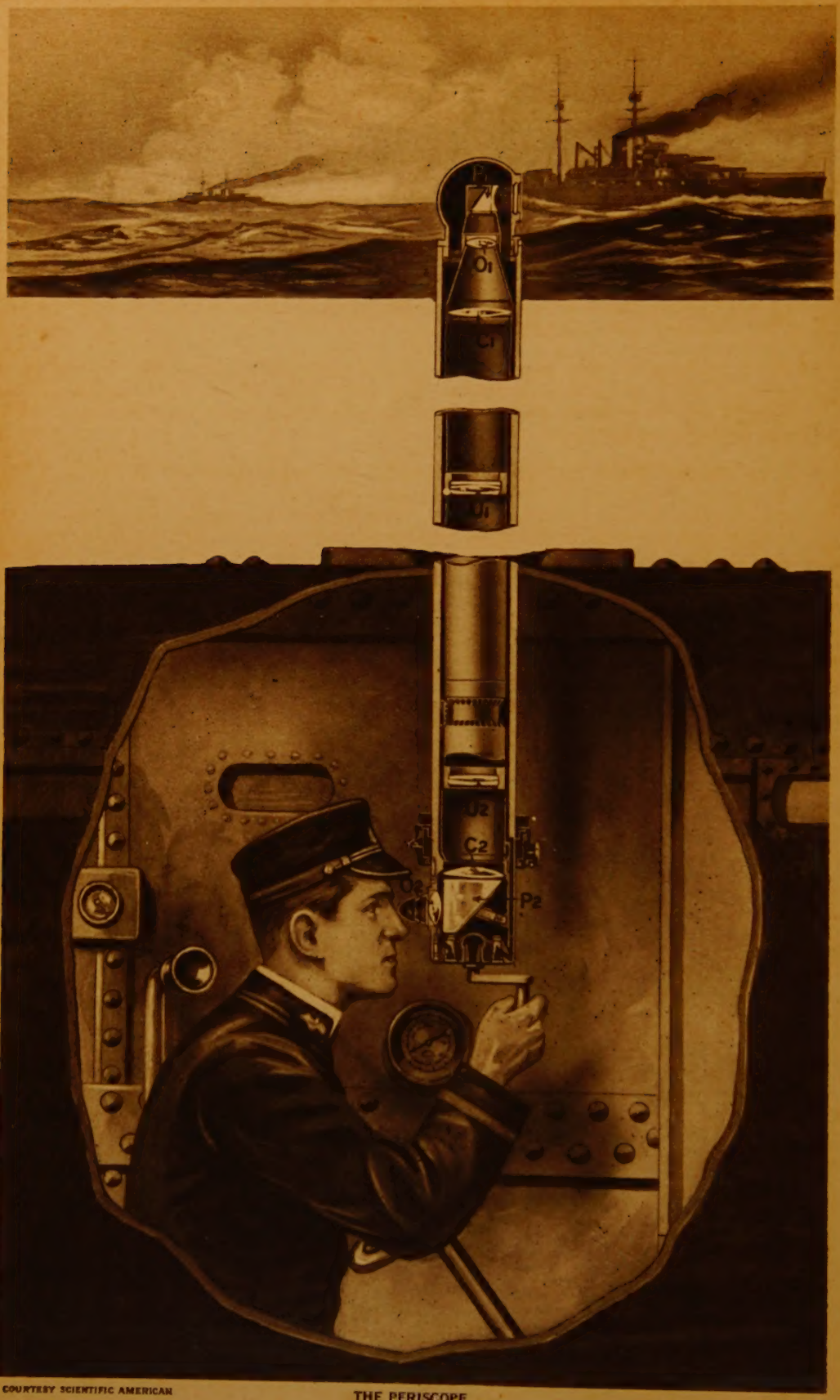


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THE PERISCOPE

# AMERICAN OPTICAL GLASS

NOT AN OUNCE OF OPTICAL GLASS was made in the United States before the war; ere its close we were turning out twenty tons a month.

Prior to August, 1914, all American optical glass came from a few German, English, and French makers. The war at once cut off the German supply, and practically all the English and French product was requisitioned by these nations.

The United States Government found itself suddenly faced by the necessity of creating its own optical-glass industry. Several manufacturers started work on the problem. The Bureau of Standards at once began research work in this field, setting up its experimental furnace and auxiliary apparatus in its Pittsburgh plant in the winter of 1914.

★ ★ ★

This pioneer work proved of great value. At the time of the declaration of war between the United States and Germany considerable progress had been made. There was need, at once, for very much larger quantities of optical glass. Conferences were held, and it was realized that energetic measures must be taken at once for a great expansion of the small optical-glass industry. In this work many agencies cooperated. The Bureau of Standards enlarged its Pittsburgh plant, and placed at the disposal of all interested the results of its preliminary experimental work in this field. The glass manufacturers provided enlarged facilities. As a result, the emergency was successfully met, and optical glass of excellent quality was soon being made in quantities sufficient to meet the multifarious needs of Army and Navy.

★ ★ ★

What of the future of this industry in the United States? Commercial and financial considerations will undoubtedly prove of paramount importance. At least two of the firms at present manufacturing optical glass propose to continue in the field; several others, which have engaged in the work to assist in meeting war needs, will cease manufacture soon. There is little profit in this product, and some patriotism will have to be combined with the profit or loss of the balance-sheet. It is not, and never will be, a very large industry, important as it is for the scientific independence of the country. American manufacturers are making as good optical glass as that of any foreign firm. Can those firms that will continue in the production of American optical glass meet the post-war competition of foreign cheaper production? This is a matter for the earnest consideration of those that desire to see America independent in this essential and important industry. It appears from assurances of students of the subject that "this country shall never again be permitted to become dependent upon foreign optical glass; we can and will make our own."

From *The Literary Digest.*

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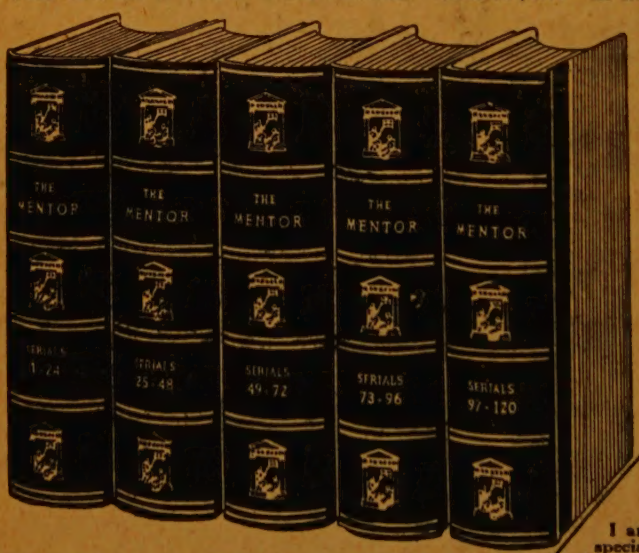


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